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# *How to Obtain a Deep Water Port on the Gulf.*

By Lewis M. Haupt, C. E.

The subject upon which I have been requested to address you is one of supreme importance to your constituents. It affects the welfare of the entire country without reference to section, since it will operate to reduce the cost of food products and raw material, and to facilitate the distribution of the elements which enter into the composition of all manufactured articles, thus extending their market range.

If you will consider for a moment the difference in the cost of moving freight by rail and by vessel, you will realize the enormous economy which may be effected by increasing to the utmost our natural commercial resources, and of carrying by sea wherever and whenever it is possible.

For instance, if we take the ton-mile as the unit, and the cost of moving the load over this distance as the measure of the relative economy of water and land traffic, we shall have for the average cost by rail, we may safely say, *one cent* as compared with *one mill* by water. In other words nine mills per ton per mile may be saved by transporting freights on the ocean, instead of overland.

The average distance to market on a large part of the products west of the Mississippi may be placed at 1000 miles, and since the *saving* in rate is 9 mills, this would give $9.00 per ton for the 1000 miles. If the annual traffic is only 50 million tons, could this be sent by water instead of by rail, it would

result in an economy of $450,000,000. If the length of the water route were double that overland, it would leave but 8 mills, or $400,000,000 saved on this traffic. These figures are not assumed to represent the general actual conditions, but they are within the bounds of possibility, and will serve to illustrate the great value of a merchant marine, and of safe and capacious harbors. From this it will at once appear that the six millions asked for in this bill is an insignificant amount as compared with the prospective benefits. It is not requested by Galveston alone, nor will it be expended in the interest of a locality, but it must inure to the general benefit of the whole country.

But before the appropriation is made, there must be a reasonable assurance that the results will be equal to the demands, and to this end the opinions of competent engineers should be accepted.

It is with reference to the probable results of the present plan that I shall particularly address you, and I do not desire to advance opinions but the logic of facts.

It seems almost unnecessary to follow this line of reasoning as to the superiority of the water way to its logical conclusion, to show that the traffic of the railroads would be increased, and not diminished, since most of the ocean tonnage must be brought to the seaboard by these land lines, and be in turn dispersed to the interior by them, and it requires hundreds of car loads, of even 30 tons capacity, to fill an ordinary steamer.

That *facilities create traffic* has been abundantly proven, and this bill to appropriate a large sum for Galveston is a laudable effort in the right direction. A deep water port on the west Gulf coast would reduce the cost of beef, cotton, grain and many raw materials to the citizens of the Eastern, Middle and South Atlantic States, and hence we have a direct interest in

securing this desirable result in the shortest time, and at the least cost.

These then are the points upon which I assume you would wish me, as an engineer, to throw some light, and they are the points to which I shall address myself specifically.

I premise that you desire to know, in the absence of any assurance on the part of the various Boards that have reported upon this admittedly difficult problem, what the probable results will be from the work if completed upon the approved plan, that your action, whatever it be, may be endorsed by a critical public opinion, not only now, but in years to come.

The problem is complicated not only by its peculiar physical conditions, but by social, financial, and geographical complications. I shall, however, confine myself, as far as possible, to an explanation and intepretation of the physical conditions, showing from the charts and models the existing forces and their effects.

First then. What are THE FORCES available for the improvement of the Galveston Entrance?

They are in general as elsewhere, the winds, waves, tides and currents, but their relative values are peculiarily variable.

## GENERAL CHART.

Without describing the physical features in detail we find here an exceptionally large inner bay covering 450 square miles but, as quoted in the report of the Board of Engineers on a Deep Harbor in the Gulf,* "unfortunately the tidal oscillation which supplies the only constant power available for deepening the passes through the cordon (of sand) is only about one foot high. Hence the volume of tidal flow to and from the lagoons is ordinarily small, and the currents conse-

* Ex. Doc. 56, 51 Congress, 1st Session. Page 4.

quently weak, notwithstanding the immense areas of many of these basins. When, however, long continued south-easterly gales have raised the water level behind the cordon several feet, a sudden norther will force out an immense volume, and in so short a time as to generate a current destructive to ordinary contraction works."

But since scour is a function of volume and velocity, it is of vital importance that this full tidal prism be admitted to the inlet and inner bay to maintain the currents in the harbor and prevent its shoaling.

If the plans for improvement do not admit of this, then it is necessary that the reduced prism should have sufficient energy and be so controlled as to scour the desired depth over a limited section of the bar, and the depths inside must be maintained by dredging.

It is manifest that the proposed jetties, although 7000 feet apart at their outer ends (called the gap), must invert the trumpet-shaped shore line formed by nature and diminish the inflow.

To what extent is shown by the Report of the Board of Engineers of 1886*, wherein it is said—in substance (page 15). That even were the full size of the present gorge or inlet preserved and a channel of this sectional area extended out to the gap, the velocity would be reduced from 3.1 to 2.4 feet per second and the *tidal influx would be reduced "about one third,"* and the same paragraph goes on to state that if "the interval between parallel jetties 29,000 feet long were narrowed from 6825 to say, 100 feet the fall through them" only increases by some such quantity as one tenth of a foot ($1\frac{1}{5}$ inches) "and the maximum increase in velocity, therefore, would not ex-

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* Ex. Doc. 85, 49th Congress, 1st Session. H. R.

ceed six per cent. These computations, (they add), show very clearly that narrowing the interval between the jetties below 7000 feet, no matter to how great an extent, gives very slight increase of velocity through them." Continuing they say, "Diminishing the interval between the jetties from 7000 to 3500 feet changes the difference of level between the bay and gulf but slightly. Through the opening of the same depth and double width, about twice as much water will flow in and out, but as it flows through a double cross-section its velocity is nearly the same. There is then very little to be gained in the way of velocities or of depths that will be maintained by them, by narrowing the interval between the jetties to *2000 feet*, as proposed by Mr. Eads to the River and Harbor Committee, May 22d, 1884, as reported in the Galveston News of June 2, 1884," as follows:—

"Mr. Bayne—Nothing like 12,000 feet? Captain Eads—That is a matter I should take into serious study before I should determine what particular width and direction I should give, but I do not take it to be over 2000 feet."

This quotation, Mr. Chairman, contains the most important feature of this entire problem. It shows a serious disagreement between *authorities* as to the width between the jetties, and it is self-evident that the logical conclusion and the only conclusion in fact to be deduced from the opinion of this Board of Engineers, as above outlined, is that there would be a larger tidal volume and hence a greater scour *by omitting the jetties entirely*—thus saving their cost and preventing an injury to the harbor.

I repeat, sir, that if the quantity of water and its velocity varies about as the area of section, as stated above, then there is no use in building these jetties. But, sir, there is an element which is potent in producing results, and which this

eminent Board of Engineers have evidently overlooked for the moment, while opposing the contracted entrance as proposed by Captain Eads, and which this engineer evidently fully intended to utilize, and that is the principle of REACTION. The same precisely as is to be found developed by the concave bank of every stream; the same that has been recognized and applied successfully by a few foreign engineers in designing harbor works. But before I undertake to show to what extent this agent may be applied at Galveston, permit me to continue the quotation.

The report goes on to say:

"But there is very much to be lost. A reduction of the entrance width to 2000 feet would reduce the amount of water entering and leaving Galveston Bay during a tide of one and eight-tenths (1.8) feet to about one-fourth of its present amount. The tidal channels which are now kept open by this water would shoal up; it would probably ruin Galveston Harbor proper, and very largely diminish the depths at the Bolivar Gorge. Aside from the great damage it would do to all the tidal channels now existing inside of the outer bay, it would also increase the danger of injury to the jetties in great storms. In such storms, with winds from north-east to south, Galveston Bay, as already seen, may slowly fill to great heights; if, then, the wind suddenly shifts to north or north-west from south, the water is driven out with high velocities. In 1875, in this way a deep channel was cut across the eastern end of Galveston Island, and the main bar was cut down. Such storms will endanger jetties 7000 feet apart; if made narrower, the time of outflow would be prolonged in proportion, and hence the danger of undermining the jetties and of cutting channels across Galveston island would be still greater, etc."

This special plea against contracted jetties contains a great

deal of truth which has been verified by experience, time and again, and the inevitable conclusion is reached that such a jettied channel should not be built, if the welfare of the city and inner bay are to be regarded.

Again in the recent report of the Board of Engineers of '89 on a Deep Harbor in the Gulf, occurs this statement as to the proper width of entrance.

The "conditions, as definitely stated by the Board, are, that an entrance shall be maintained with a continuous width of at least 2000 feet, and a channel depth of 30 feet over a width not less than 600 feet, the two involving a sectional area of about 43,000 square feet."

This is the minimum navigable channel believed by the Board to be permissible, and yet it is more than twelve times the size of the section given to the Suez canal, which is still able to carry the commerce of the world.

But this minimum channel is entirely too large to be created or maintained by the enfeebled currents existing at this place, and dredging will not avail, as I shall presently show.

This requirement means, either that the jetties must be contracted to a width of 2000 feet at the gap, which, in view of the preceding objections to such width for the Eads plan, [redacted] would be so inconsistent as to be incredible, *or* else that a channel of 2000 feet wide at the surface, and 600 feet at the thirty foot contour with a depth of 30 feet, and an area of 43,000 square feet, must be maintained by the scour produced by jetties 7000 feet apart with a tidal prism of not more than 70 p. c. of the feeble original volume. And this, sir, is an absurdity. *Moreover.*

Concerning the depth to be obtained from the jetties, 7000 feet apart, the Board predicts that, "on the whole, therefore

there is reason to expect that the pproosed jetties, when the channel is once formed, will maintain some such depth as 25 or 30 feet. They will maintain practically all the depth that could be maintained by tidal currents between any jetties however near each other, but will not involve the dangers already specified by close jetties."

This is conclusive as to the ignorance of the reaction principle, and although it mentions a depth as a possible one, yet in the next paragraph it is stated: "Such predictions can best be made by those ignorant of experience in tidal entrances elsewhere, and having great confidence in the credulity of mankind."

The latest Board (1889) however say, "In the opinion of the Board it is possible to maintain an entrance of ample depth and width at one point on this coast without much if any dredging for maintenance." This entrance as already stated is the minimum one of 43,000 square feet, 2000 feet wide and 30 feet deep.

It becomes therefore a very difficult matter to steer between the Scylla and Charybdis of wide and narrow jetties, or of none at all; and there are those who rely confidentially on the present jetty plan because it is *thought* that it is substantially the one proposed by Captain Eads. Such however *is far from being the case;* whilst the section and material of the jetty may be that proposed by him as the basis of his estimate, the answer above quoted from Captain Eads show conclusively that he did not sanction nor approve any width exceeding 2000 feet, but believed it should even be less than this limit. He evidently had not definitely fixed upon either the width or direction to be given to his project, at that time.

## THE REACTION PRINCIPLE.

To show that jetties over 2000 feet apart will not materially increase the depth, let us examine first the results of the resultant forces acting upon this bar as revealed by the surveys.

Before any improvements were undertaken it is reported that the depths varied on the bar from 10 to 13 feet. This then was the depth of scour with a full tidal prism. Now, after the south jetty has been extended over 15,000 feet towards the bar, and a large portion of it is raised above the surface, the depth of scour on the bar is 13 feet 3 inches or a few inches greater than existed before the works were commenced. Concerning the anticipated results the Board of 1886 stated.

"Since carrying the south jetty out to the bar will reduce considerably the water cross section on the bar, the velocities and depths there should be somewhat increased by that jetty alone. When both jetties are completed to the bar there is reason to believe that they will, when their full effect is produced, give depths about two-thirds of those which the jetties carried to the 30 foot curve will give," and they add: "As the jetties will diminish the freedom of inflow at Galveston they will tend slightly to enlarge the San Luis Pass. It should therefore be watched."

The present condition of the bar shows no lowering of the plane of tidal scour other than that due to the slight reaction produced by the head of the jetty where the depth is about 13 feet for a width of several hundred feet.

The recent charts, having no depth marked on them, it is not possible to be more specific.

This is because the reduction in the flood tide section is equal to that of the ebb, and although there is still a large sector open the navigable channel is not materially improved.

Now if by the construction of the north jetty another large section of the area of ingress is cut off there is no reason to suppose that the enfeebled prism left will cut any deeper.

Again if the area between the jetties be enlarged by dredging it will merely reduce the velocities and induce more rapid deposit than before. Dredging has already been tried between the jetties at Charleston and many other places, and abandoned as hopeless.

But the last part of the above quotation may contain a ray of hope; for if, by building jetties at Galveston, the San Luis Pass, twenty-eight miles distant, may be slightly enlarged, then it would certainly seem rational that, to improve Galveston entrance, the jetties should be placed at this remote pass, or the pass should be closed entirely.

Strange as it may seem, the Board of '89 appear to have avoided the question of the cost of dredging their minimum channel across this bar, by the simple statement that they believe "it is possible *to maintain* an entrance of ample width, etc." They do not say to create. But what a current cannot create it cannot maintain, so that it may be presumed both functions were intended. Permit me to present an estimate of the cost and probable time required to create such a channel as has been decided upon, as the least possible. Assuming the crest of the bar to be at 12 feet depth, the amount of material to be taken out to join the 30-foot curves across the bar is 6,365,400 cubic yards. The best hydraulic dredgers have removed 1,527,000 cubic yards in 26½ months' working time (including delays). At this rate with the best plant, it would take four such dredgers over two years to make the cut, and at only 33 cents per yard it would cost $2,122,133.33. Yet the cut would fill about as fast as it could be dredged, and there would be no end to it. There are some projects, Mr.

Chairman, which will bear a little investigation before they are entered into. Witness, the Panama Canal.

In these millions of tons of water at Galveston there is an enormous amount of potential energy, which only needs sufficient head to render it kinetic; but the farther out the jetties are built the less is the slope between gulf and bay, and the greater the loss of head. Already this distance has been increased by nearly a mile and a quarter since the works began.

This latent energy of a stream can only be developed in work when it meets with an obstruction upon which it can *react,* just as in the case of a projectile which gives out but little energy until it meets with an obstacle, when it is developed suddenly, and a large portion, if not all, is expended in heat and the work of destruction. Then the mass becomes inert. It cannot give, however, more than it has. So with the tidal currents; if unobstructed, they glide gently over the bars or are deflected by them; but when opposed by jetties or other obstructions, they react along the faces of those works, and scour channels more or less deep according to the energy of the living stream. What this amounts to at Galveston is seen to be only a shallow groove reaching to but 13 feet depth on the bar. Yet in the gorge it is said that there are depths of nearly 50 feet; and it is claimed, because the ebb produces such depths here, the same forces, if made to act on the bar, would produce equal results there.

This error has been frequently repeated, and its fallacy is to be found in the fact that it is not the *ebb* but the *flood* which in general produces the deep holes in the gorges found at these inlets; neither is it due to mean velocity, but to the boring action of convergent streams approaching a contraction, where the waters are momentarily restrained by the obstructing shores,

—the head is increased and a reaction produced on the bottom which drives them through. This can be verified by noting the position of the point of maximum depth with reference to the area of greatest contraction. It will, as a rule, be found on the side from whence comes the greatest scour. Numerous instances might be cited to prove this important feature, but I will content myself with one or two.

At the narrows in New York Bay, for example, a Board of Engineers once said a mean ebb velocity of two feet per second produced a depth of one hundred feet. Why then do velocities of over three feet upon the five mile bar only scour to a depth of nine feet or less? The surveys show a depth of 114 feet below the least section, and a resultant flood movement for eleven hours out of twelve. Around the ends of the Delaware Breakwater similar features are observed always on the side of the greater current.

The jetties at St. John's River show the same deep hole and waste of energy by the abrupt change of direction given the ebb stream at the point of incidence, where a large part of its energy is wasted upon the jetty, which it tends to destroy more rapidly.

To produce a similar hole at the head of the jetties, it would be necessary to create a similar compression of the flood by extending the present jetties, in a funnel shape, a considerable distance seaward.

Otherwise there must result a silting up of the space inside of the gap between the jetties due to the expansion of the fluid prism as it passes in charged with sand. This expansion reduces the velocity and the sand is deposited in the middle ground invariably present where the jetties diverge inwardly and are far apart. A remarkable instance of this is to be seen at Manasquan, N. J., where in a short time after the jetties

were built the entire space between them was filled to the top of the jetties with sand and the channel was diverted some distance to the southward. Here, too, the jetties were internal and so designed as not to reduce the flood volume, while they were intended to concentrate all of the ebb. The tide is only about one foot, or the same as at Galveston, and the tendency of the ebb at this place is to cut off and isolate the jetties by passing southward across the Fort Point Peninsula making the shore extension necessary.

This instance will serve to show what may be expected from improperly designed jetties.

The accompanying prints are from the Reports of 1882, 1887, and a sketch by myself in 1889 confirmed by photographs. (Not reproduced herein).

But, Mr. Chairman, to return to Galveston. The jetties, 7000 feet apart, cannot co-act to produce scour. The limit of the width to which a channel of only 20 feet depth, with tidal fluctuations of over five times those at this point, and with double the velocity of current does not often exceed several hundred feet, and even then only so long as a continuous reaction is maintained. Here at Galveston, with the reduced tidal prism, I should not expect, reasoning from analogy, to find more than say 15 feet depths on the bar crest immediately inside the jetties when completed, and for widths of perhaps 300 feet each. In other words, I believe the jetties might possibly maintain, if placed only about 600 feet apart, a depth of from 15 to 18 feet between them, depending upon wind and other conditions. But such a width here would utterly destroy the inner harbor upon which the Board of '89 count so confidently for refuge.

The present divergent or convergent plan is bad, and the width entirely too great to produce any such results as are

desired and predicted as requisite to meet the demands of commerce.

I repeat, therefore, that in the light of experience here and elsewhere it is hopeless to attempt to secure a deep-water channel by the jetty system, and to continue this prodigious experiment merely postpones the evil day, increases the losses and disappointments incident to failure, and would be a useless waste of public money against which we feel it a duty to enter an earnest protest.

But, Mr. Chairman, I do not wish to leave the problem in this predicament, nor your Committee under the impression that the profession of Civil Engineering is not equal to the emergency. I realize that as an objector it becomes a duty, if possible, to submit a remedy. To this end I have given this question of harbor improvements my serious attention for years with the object of fulfilling the fundamental yet apparently conflicting condition of 1st, *Keeping out the sand;* 2d, *Letting in the tide*, and 3d, of designing a structure of such form and position as will develop and *maintain a continuous reaction over the bar.*

This plan, sir, I submit as being one that will produce the best result obtainable at this entrance, and I believe it to be the only salvation for the city of Galveston.

It is said, it is never wise to swap horses in the middle of a stream, but, sir, when one's horse is sinking, I believe it to be good policy to mount another if it appear to be a better swimmer.

It has been said also, that this plan has not been recommended by the Chief of Engineers, and Congress will not go beyond his dictum. To this, I would respectfully reply that, as in the case of the South Pass, there are instances where the importance of the issue is such as to justify an intelligent

body of representative citizens like yourselves in taking positive and definite action. In fact you are the only Court of Appeals competent to decide upon a question so intimately affecting the interests of the people of the United States.

This is the plea which I have to make for Galveston, or for Charleston, which is in a similar strait, but in behalf of the larger territory west of the Mississippi, I would add that the latest and best foreign practice is to ignore the sand bars altogether and to build a deep-water outer harbor off-shore wherever the physical conditions are most favorable.

Such harbors are now in existence, or building, at Madras, Colombo, Kingstown, Alderney, Dover, Ceara, La Guyara, and many other places. They are safer, more capacious, cheaper, more accessible and can be built in less time. Certainly the story of the Samoan disaster is too recent to be forgotten, and it is an impressive example of the dangers of inner harbors defended only by low sand spits.

If, therefore, it is your purpose to accommodate the greatest number of citizens and to loan the credit of the United States to develop the largest territory, tributary to a deep-water seaport in this federal domain, it can, in my opinion, best be done by encouraging the construction of the Corpus Christi and Padre Island Harbor Company's project, for which a bill has already been presented, and which will cost the Government nothing, but, if in your judgment, it is better to continue the experiment at Galveston, with over $6,000,000 worth of work in sight with no gurantee as to results, and no prospects of obtaining any under existing plans,and with no knowledge of the ultimate cost, then I should respecfully urge a radical modification of the plans which would give greater promise of beneficial results at less cost.

The plan which I respectfully submit as that most likely to

produce a satisfactory result is the one unanimously endorsed by the American Philosophical Society, slightly modified so as to adapt it to this peculiar locality.

Briefly, it consists of a substantial breakwater and sand-barrier of rip-rap, of such form as to change the conditions of equilibrium of the existing flood and ebb movements in favor of the ebb, to conserve its energy and maintain a continuous reaction on the lee side of the breakwater and to increase materially the surface-slope and consequent velocity of the ebb, but not of the flood over that portion of the bar which it is desired to remove. These are but a few of the features and results incident to this system of Harbor Improvement.

The laws of God are immutable, and however much we may desire a deep channel between jetties 7,000 feet apart with a weak tide, and 33 per cent. of that cut off by the jetties, it is not possible to obtain it. We cannot create a power which does not exist, but we may utilize all there is by an intelligent application of these laws to the physical conditions existing at the site.

*Non Dei leges mutare, sed in hominum usum adhibere.*